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## SPECIALIZATION IN PREPARATORY NATURAL SCIENCE

IN my address at Milwaukee in 1897, I led up to this idea in consideration of the best ideals and most available material at our command in the high and preparatory schools. (Proceedings N. E. A., 1897, pp. 917-923.)

On further study I am more than ever convinced that this idea has come to stay. We find it already working itself out, under our dim and sluggish eyes, and we have been almost reprehensibly tardy in recognizing it. Any work done, in a radical rearrangement of our preparatory natural science courses, will be largely wasted unless we take full account of this all-important factor.

For convenience we will consider some of the arguments in order :

### I. The Analogous Preparatory Classical Course.

The real admission of natural science to the preparatory curriculum dates from 1883 when Charles Francis Adams, in his celebrated address at Cambridge, pleaded for a substitute for Greek as a fundamental element in practical college culture. How slow we have been to take advantage of the tide which has been carrying us onward faster than we have realized !

The older colleges—if I understand them—confess that the problem is mainly to find a substitute for Greek. Of course this looks like a timid confession of indifference to the great claims of natural science (and the modern languages), but at least it gives us something definite to talk about: *A substitute for Greek*. This is not indefinite. Preparatory Greek is not a jumble of nine or ten three-months' courses of anything—not a set of three or four one-year courses of different things; but a clear, hard, business proposition of *three or four years' work on one thing*.

Now, whether we shall be able to find a substitute for this

may be an uncertainty in some minds ; but, if we find it, we certainly shall not find it in short, choppy, superficial courses in many subjects. The whole magnificent history of the old fashioned preparatory course advises us, with all the emphasis of its complete success as compared with the cheap "English" courses of the last two decades, to hold fast to specialization in a few subjects in all our planning. This seems so simple and clear that I hesitate to weaken the force of the argument by tarrying unduly on it. But I do challenge every one who was working at the Greek of the high and preparatory schools a score of years ago, to answer this question: Was there not a great gulf fixed between the text-books, the students, and the work of the classical and the English courses? Was not the one *hard work*? Was not the other relatively "*a picnic*?" Could we not turn from our Hadley, our Goodwin, our Xenophon, our Homer, and take up the average text-book of the English course in much the same way that we treat the summer novel? And why? Because Greek, for one thing, meant hard work, hard beyond comparison with any alternative taught in the English course. Then, in granting an option, let those of us who consider natural science only as it may offer a substitute for Greek, pause to examine carefully the vouchers of the new claimants. I have spoken much and written some hard criticism against the conservatism of the New England colleges in their hesitancy to admit *good* natural science in the list of entrance requirements. But perhaps they are wise in refusing to listen to the enthusiast till he shall offer a real substitute for Greek; and if offered in natural science, it can mean but one thing, that is *three or four years' work in one science* or in such a set of sciences and so related that they may unquestionably count as one.

In emphasis of this point, let me quote a paragraph or two from my Milwaukee address:

I shall describe what I believe to be one of the best preparatory science courses ever carried on; it is the course I understand best, the course essentially to which I have given ten years of support, and with a fairly successful experience; and, further, it is approximately parallel with the standards of

many of the best high and preparatory schools in the country. It may be outlined as follows :

First year — physical geography.

Second year — physics.

Third year — chemistry.

Fourth year — biology,

Now, to illustrate the comparative weakness of this, allow me to suggest a scene for you to construct in imagination : Let us suppose that the historical course of education had been reversed, and that natural science, well taught for centuries, were holding dominant sway in all the schools of learning to the exclusion of all philology. Suppose that suddenly a new wave of language study should advance in rivalry with the old scientific culture. In such hypothetical circumstances, what would the conservative natural-science people think of the dignity and thoroughness of a natural-language course of four years, with, say, one year in English, one year in Latin, one year in French, and one year in German ? Now, such a language course could claim all the arguments advanced for our course of four sciences of one year each. But would our supposed science censors listen for a moment to such a feeble, incoherent, undignified proposition ? They would refer it back indefinitely, until the language people should present a course representing some simplicity, strength, and thoroughness.

## II. The Necessity of Recognizing Electives between Specialized Classics and Specialized Natural Science.

The arguments for the recognition of the principle in theory are too familiar to need comment here. Such recent articles as those of Mr. C. C. Wilson (*THE SCHOOL REVIEW*), of Professor R. S. Tarr (*The Journal of Pedagogy*), and the discussion in the May number of the *Educational Review*, illustrate the irresistible tendency of the times in asking for a worthy alternative to specialization in Greek. Now this is very good — in theory ; but what do we find in fact ? Simply this, that at present, as a rule, there are no highly specialized courses in the secondary school curriculum which, in discipline and thoroughness, compare with the classical course.

I am told everywhere and all the time, by broad, liberal teachers in high schools, men who recognize the full value of natural science, both for discipline and culture (are they not identical ?), that they are compelled to advise the best students

to take the classical course because it is the only one offering opportunity for genuinely hard and continuously hard work on the same subject.

So, then, we have no real alternative to Greek yet offered in natural science. We shall not have it until we provide similarly specialized work.

I know that this may be very trite to many readers, but it is well to emphasize the point. Our conservative reader will say that it is not possible for the secondary schools to offer such an alternative, at least at present; and meanwhile why trouble ourselves about experimenting with that which will surely take much time and give much trouble?

The answer is, and many of us feel certain about it, that the preparatory ultra-classical course is not suited to develop all minds to their best advantage. I recall several students who, beginning with me in secondary work and following on to college, have specialized from the very first in chemistry. As students and men, they are as strong, broad, and growing as any parallel products produced by the classical course.

And as a matter of fairness, those of us who are interested in natural science, must claim the right to offer the bait of specialized work that we may catch our share of the good fish. Indeed, good minds among the students of natural science are as indispensable to the right development of these courses as they are for the preservation of the classical courses. Is not this right? I believe the time has come when all good teachers want only those students who should naturally come to them.

This then is our second argument; we need, and at once, highly specialized courses in natural science to meet the wants of a large half of our best students in the secondary schools.

### III. The Necessity of Offering Electives Between Highly Specialized Branches of Natural Science.

This argument, tending towards certain specialization, is based on the amount of work asked by each specialist, and the place he prefers in the course, as he becomes more interested in the preparatory science curriculum.

Now, each of the fundamental sciences cannot monopolize all the time, nor have the pick of the time, except in one way, and that is, by allowing the student to elect between alternative specialized courses.

Those who have worked on such courses, know what pranks physics has played with our supposedly good, one-year sciences. And at present we see that physics, in compounding with mathematics, has outstripped the rest of the sciences.

Well, what is to be done? Are the enthusiasts in mathematics and physics wrong in their unconsciously selfish effort to rearrange our preparatory science till they gobble up most of the time? Not at all. They are right; they are simply working out the inevitable tendency towards specialization, and we need not fear it one bit. Simply let us ask that all students be not required to specialize in mathematics and experimental physics; but that the non-mathematical ones be allowed an option on similarly special courses in chemical or biological or physiographic science.

And here I may venture the suggestion that our committee will satisfy neither themselves nor the times unless they work their way out to alternative specialized courses nicely adjusted and coördinated in election.

#### IV. The Inherent Power in Natural Science for Discipline.

We come now to the *positive advantage* of specialized work in natural science—the one great argument. Most teachers recognize both the *disciplinary* element and the *information* element in natural science; each contributes to the other; both help the student in making himself a student. But, if either is the more fundamental, can we hesitate a moment in pronouncing for the disciplinary element? Would not any other judgment amount to a failure to realize what natural science is?

The main steps in the inductive method—and this inductive method is only systematic *common sense* applied in observing, registering, comparing, all of it in a word is only orderly common sense in studying, for our purpose, the material world—have we not covered here the main steps in the inductive method?

Now, this is the point, viz., can this systematic common sense in natural science study be carried to the degree where the method may attain real value of discipline in thinking, unless we carry it on continuously and in logical sequence so that it involves specialization? If we take any other position, do we not at once confess that we doubt the disciplinary value of natural science as one of its chief features? But we all are really agreed about this; then why not apply it, and at once? Why not hold consistently to the main point, viz., that most of us of a material bent, learn to think by bringing our minds into close and accurate touch with material things? I do not say there is not another side of culture, of vital importance to all, but we are now discussing the material side.

Now, if this has been logically developed, if careful, orderly, long-continued work on a few things involves discipline (and the best discipline, as I believe), why not hold to the position and apply it?

Now, mental discipline grows cumulatively, by training the memory, the best memory, which remembers because the mind learns easily what it understands; and continuous work in one line cumulatively helps the mind in conceiving what is continuously studied. This of course is known by all of us. Why do we not apply it?

Hence the first, great, positive argument for specialization is found in the disciplinary element.

V. The Inherent Power in Specialization to Provide the Requisite Collateral Information—Supplementary Reading.

Now there are several lines of natural science, and the well informed student must have at least a general acquaintance with all. How can the student get the merely informational element in all of these lines if he is specializing only in one?

This may be done in two ways—firstly, by short half-year introductory courses in the subjects other than the one specially worked at, and secondly, by supplementary reading, and this point deserves a large paragraph.

If there is any one quality common to all mental culture, it

is probably this—the power to fix and hold the attention on the subject in hand, whether it be a text of Xenophon, a problem in geometry, an experiment with the transformer, a separation of two metals, or the dissection of a lobster.

Now this ability of the specializing student, whether he be a classical, literary, or scientific student, this ability to hold his attention to one subject for close observation and accurate thinking, this is the one quality which in my experience marks the great difference between the specially trained student, and the student who has dipped into many things without thoroughness in any. The difference has been referred to in the earlier part of this article, but it needs emphasis and continued reiteration. It is the main thing we are talking about—the development of students; and it holds good for students of secondary grade, because our stock illustration is drawn from the old preparatory course.

Some of my classical friends, from this confession of the inherent strength of the old preparatory classical course, may reason that it is the best preparatory course for all; but I am not afraid of that; the old preparatory classical course has its strength, and, for the student of natural science, its weakness; but that has been already referred to under argument II.

Of course we assume that the preparatory natural science curriculum refers to only about one-fourth of the work, and the rest involves Latin, German or French, English, history, literature, and mathematics. But, to hold to the main point, discipline of mind carries the inherent power of concentration of attention *on any subject*. And here we find another great, positive argument for specialization (both in natural science and also in other lines). This self-control of concentrated attention can be easily, economically, and effectively employed in bringing up the collateral and supplementary reading. This must be considered, for it is the main argument to be put forward against the often alleged narrowness of specialized courses.

I conceive it quite possible that the average special student of natural science in secondary schools may, by judicious advice



and wise economy of time, cover, in supplementary reading, as much ground and as well, as that covered by the average student in the average non-classical or non-specialized "English" course, *in toto*. I believe the average specializing student can do all this and keep his special work well in hand at the same time — and all by reason of his power to do intensive work.

I might give illustrations in which I have seen this done. I will mention that I have seen the elements of physics, chemistry, mineralogy, geology, astronomy, natural history, history, English literature, etc., covered in the high school, without direction and without encouragement, by one who was at the same time a specializing classical student, a fair swimmer, skater, and ball player; and all this general reading was taken up merely in the way of recreation.

Now this is possible. I doubt not that many of my readers, experienced teachers of specialties — could parallel or outdo my statement and yet keep far within the limits of historic truth in their personal history. But the point is, that, after giving the student the power to do *intensive* work, he will take the main responsibility in providing himself with information drawn from *extensive* reading; he must, he should, he will. It is perfectly safe to leave the responsibility there with the judicious advice and assistance of the wise, cultured teacher.

If then we concede that specialization does this, if it equips the student when under wise direction, to guard against narrowness by providing for the information element also, if these main points are covered, viz., (1) thorough knowledge of one subject, (2) power of concentrated attention, (3) power to acquire outside information, what more can be asked of a prospective system?

VI. Discipline in Natural Science as a Basis for the Later Study of the More Abstruse Sciences, such as History, Economics, etc.

The inductive method is the same wherever applied. We sometimes carelessly use the term "science" as though synonymous with "natural science;" we forget that the abstract sci-

ences are, or may be, just as truly sciences as the concrete. Now, does it not seem reasonable that many students will have a better equipment with which to grapple with the science of the partially abstract, if they first learn the common sense (inductive) method from the concrete, where observation may be easily made and tested?

As a matter of fact, I have had occasion to recommend many of my best special students in chemistry, to take courses in history and economics, and invariably they showed unusual power of grasping the relatively intangible by reason of their power to grasp the tangible. Many good students who lose their way in the abstract sciences, might retain a common sense control of their work, if they had been previously equipped with training in the concrete. This is a strong argument and one that will well repay attention and practical application in our curricula.

#### VII. The Ethical Argument.

But we may go farther—the ethical element? Yes, for students of natural science make a specialty of applied ethics. This is not humor; it is in most sober earnest.

In general, as President Thwing remarks in a recent article —“hard work is an enemy to easy morals;” and hard work in natural science will illustrate this sound doctrine. But in more detail, is not the knowing of some few things thoroughly the best basis for the honest and right prosecution of those subjects? In learning how hard it is to know the truth in a few things, does not our student have honest thinking stamped into his whole mental and moral make up? Then there is a moral force in specialization. Universal superficiality is immoral.

In this age of active, branching thought, there is one unifying agent, among the many articulating elements of culture, which needs emphasis. It is this: honest leaders in different lines respect each other; they are frequently intimate friends—not because of common information along the same lines, but by reason of the specializing power and its inevitable result. They reach down, unconsciously perhaps, into the deeper foundations where all is cemented by the spirit of thorough honest work.

This point finds too common illustration to require much comment. A specialist in Latin, history, or economics, "chums" with a specialist in physics, or chemistry, or biology—why? Because they are all good fellows—a very important point—and they understand each other through the pentecostal tongue of the honest specializing spirit.

This argument is worthy of great expansion, but it is enough for our present purpose to note it, and to acknowledge it. It applies itself with remorseless certainty.

#### VIII. Are Specialized Courses Suited to All Students?

After a hasty reading of this article, it might seem to follow that this specializing tendency should be recognized and its method required for all students. Personally I feel more and more inclined to follow the opinion of President Eliot, that "the best preparatory course is the best finishing course." I find, in this, a guiding idea in our present maze of opinion and rapidly changing opinion. But it may require careful application.

Most laboratory conceptions require some modification when applied on a larger scale, and in competition with economic factors. Many of our taxpayers think they want a "general" course; they have had it; they have it. But more serious than this (because the taxpayers are reasonable people, they will listen to sound argument, and they can be led around to reasonable views, especially if it can be shown that the specialization idea is, for the student, the best economic idea)—there is another fact—I fear it is a fact, though I wish it were not and hope it is, at worst, only a temporary fact. It is this: all scholars apparently have not the making of good students in them. Our course, as we have planned it, implies brain power in all students; the implication is not always justified. I must confess that in my experience, as a rule, the feminine sex is incapable of holding to the work implied in chemical specialization. At least the lesson is a clear one, that all scholars are not fitted for all specializations. Yet I have found that many, incapable (perhaps through lack of interest) of natural science specialization, are yet quite capable of good specialization in other lines,

as language, history, literature, all of equal value in our cosmopolitan system. Perhaps the problem is only the selection and adjustment of the appropriate specialty for the respective student.

The making of a good student often depends also on many factors not commonly considered—an undying love of knowledge, a cordial encouragement from home influences, home influences which should ideally represent culture—a high and grand ambition. All of these factors have their influence. But all these will be of little influence if the school work be superficial.

#### IX. The Economic Argument.

A colleague, who is a specialist in economic and legal history, maintains, and I think rightly, that most settlements of large political questions are finally adjusted on an economic basis.

This economic factor is a serious problem to face, as we urge the application of the specialization idea, but it should not frighten us. If it is the best thing for the individual student economically, the people—the taxpaying people—will see it, and they will demand it. And they will not excuse us, in our implied function as educational advisers, if we advise timidly or suggest diffidently or indefinitely.

If it should appear, on more experience, that specialized courses are, as I have argued, always best for the good students, and further, if it shall appear that all students have, as we hope, some elements of good in them as students, then the economic problem is only a question of honest, courageous explanation to the taxpaying people. They will gladly support the best. They will prefer in comparatively poor (financially) country high schools, where only one teacher of natural science can be had, that he shall be a specialist. They will prefer that the large city high schools should do all their instruction through specialists, well trained and well equipped, and they will pay for it; for such special work gives the student full information in one line, it gives him power of concentration in any line, it gives him power of acquiring all requisite general information; it makes him a student in school, it makes him a man in life—what more can we ask?

### X. The De Facto Argument.

This is the practical point for us as advisers of the secondary courses—what can we do now?

If the mass of the specialists in our colleges were really alive to the requirements of the problem, and really believed, and in a sanguine way, that it were feasible, we would see many instances of highly specialized courses in natural science already in practical use in secondary schools. Our secondary schools are working out this problem, usually willing to listen most courteously to the college men, and frequently, "pity 'tis, 'tis true," receiving only cold indifference or worse still, arrogant, cruel, criticism of their best attempts.

Let those of us who are college instructors ask this question, and let us put it to ourselves. How long a time would be required to train a student to become master of any natural science? Would we be willing to put less than ten or twelve years as the limit? It is very common to find students who have put that amount of time on Latin or Greek. But (with no unpleasant comparison in mind), are the natural sciences smaller subjects than Greek or Latin? Is the literature smaller, the progress less rapid, the demand for mental and physical work less exacting?

I suspect that nearly all of what we commonly call college science is really only work of a secondary grade. And if it could be put down there and handled properly, as it surely will be—if we could receive our incoming students with a good start in specialization, then we could add to their college work, most of what is now called graduate work. And then, on this basis, graduate work would advance to what it ought to be—a *real mastery of the subject*, and a real piece of research of three or four years' work. Then we should see real leaders in science produced by our universities more commonly than we find them as yet. Hence, improvement in the secondary grades will enforce improvement all along the line, and our college specialists are beginning to realize it.

And here I would ask my colleagues, specialists in the many

colleges and universities, is it not time *now* for us to make our suggestions, now while the times are ripe? Is it not time to cease believing that it is an impossibility for the secondary schools to teach sound natural science in one or several lines for three or four years? It has been done for years in the classics. Are the natural sciences the cheap small things implied by our present secondary courses?

It has been intimated that this tendency to specialization is active in our midst, and we note that many schools already give more than a year to physics or chemistry; and in arranging related and dependent subjects, such as biology, botany, zoölogy, physiology, etc., care is taken to arrange them so that they may articulate and form as far as possible one subject. The tendency is clear; it only needs encouragement. I can see clearly that the elements of inorganic chemistry, analysis, organic chemistry, physical and electro-chemistry, the history of chemistry, etc., can be so shaped and ordered that they may form one continuous subject; and similarly each specialist in his line can plan an appropriate course, capable of practical application in secondary schools.

I know that a committee of natural science teachers in one state is even now planning a high-school course where alternatives between specialization in the various natural sciences (physics, chemistry, biology), are distinctly recognized.

If we can have the problem thus definitely stated, there is great hope that many sections and associations will shortly take up this restatement of the problem for study, discussion and immediate application.

Let us hope then that here we have found the clue which will auspiciously and certainly guide us to ultimate success. It has guided the genuine scholars of all time and they have followed it instinctively, loyally. It is the clue of specialization, *not many but much*.

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